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Effects of MOPP Configuration and Two Drinking
Systems on Fluid Balance and Performance.

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Abstract

The impact of wearing MOPP on fluid balance, thermoregulation and performance was evaluated. Fifteen male soldiers walked (4 kph, level treadmill) for 6 consecutive 50/10 minute work/rest cycles on two non-consecutive days. Conditions were 30°C d.b., 18°C w.b., and iodinated water (30°C) was consumed ad lib. On one day soldiers wore the Battle Dress Uniform (BDU) and drank from canteens; on the second day, they wore MOPP IV and drank with either the current gravity feed system (CS) or a fluid hydraulic (FH) system. All BDU subjects completed the entire 300 min of exercise, and average water intake (0.25 L/hr) partially compensated for sweat losses (SR) of 0.37 L/hr that contributed to body weight (WT) losses of 0.24 kg/hr. During work bouts, CS drank significantly less than FH (0.28 vs 0.42 L/hr, respectively). While SR was similar in both groups (0.84 L/hr) and markedly increased relative to BDU, WT deficits were double those of BDU. Increased SR and inadequate rehydration produced increases in heart rate (49 bpm) and heat storage (33 kcal/m²) contributing to performance decrements in CS (210 min) and FH (231 min). Both CS and FH perceived more symptoms of hyperthermia and dehydration, and rated their final walk significantly more difficult than their first. The results demonstrate that physiological and perceptual decrements can occur when MOPP IV level is worn during low intensity work in a warm climate, and that a FH system may improve drinking during work/exercise.

Introduction: Voluntary dehydration of 2-3% initial body weight is common when working under desert-like conditions, and increases markedly with increased temperature and poor palatability of the drinking water, increased sweat rate, and greater effort required to obtain the water (1). When fully encapsulated in mission-oriented protective posture (MOPP IV) to protect from the threat of a contaminated environment, an additional impediment to drinking is the difficulty in delivering sufficient fluid through protective mask and requisite through-mask drinking system. Recent estimates of fluid requirements when dressed in chemical protective gear and performing moderate work at moderate temperatures (70-85°F) suggest a 1-2 qt per hour requirement.

The current through-mask drinking system (CS) has several shortcomings that include increased risk of contamination due to required connecting/disconnecting with each drink, two-handed operation, and creating and then sucking against a positive pressure. Soldiers drinking with the CS have described procedures as time consuming, difficult and frustrating, and often stop drinking the required amount of fluid. Marked dehydration may be a significant problem for the soldier working in MOPP IV configuration. The fluid hydraulic hydration system (FH) requires no connecting/disconnecting with each drink, and draws water through tubing directly from the canteen into the mask via single-handed operation. Thus, the relative ease of use of the FH system may be important in encouraging soldiers to drink. This study explored the effects of wearing MOPP IV on fluid balance and thermoregulatory measures, and the physiological and perceptual differences in subjects using these two drinking systems.

Methods: Fifteen non-heat acclimated male military volunteers spent up to 6.5 hrs in a climatic chamber (29.5°C dry bulb, 18.3°C wet bulb, 33% relative humidity, with a windspeed of 8.04 km/hr) on two non-consecutive days. During this time, subjects walked on treadmills (0% grade, 4.02 km/hr) for a maximum of six 50/10 min work/rest cycles. Their physical characteristics (mean±SE) were: age, 23±1 yr; height, 175±1.1 cm; weight, 72.0±2.2 kg. On one day, subjects wore a modified Battle Dress Uniform (BDU) and drank directly from canteens. On the second day, subjects were randomly assigned to either 1) CS; dressed in MOPP IV configuration and drinking with the current water delivery system or 2) FH; dressed in MOPP IV configuration and drinking with the fluid hydraulic delivery system.

After initial nude body weight (WT) (±50g) was recorded, subjects were instrumented for assessing rectal (Tre) and skin (Tsk) temperatures and heart rate (HR) during all work/rest cycles. Following the final walk, a final nude WT was obtained. Water (30°C, iodinated 16 mg/l) was provided ad libitum; fluid intake was

measured at the end of each work/rest cycle. Total sweat loss (SR) was calculated as the difference between final and initial nude WT, adjusted for fluid intake, urination, blood sampling, and respiratory water loss. Change in plasma volume (PV) was calculated using venous hematocrit (Hct) and hemoglobin (Hb) samples (2) drawn before starting the first walk and immediately upon completing the final walk. During the rests, subjects sat and answered brief questionnaires rating the difficulty of their walk. An Environmental Symptoms Questionnaire (ESQ) was answered pre- and post-exercise.

Results & Discussion: All subjects wearing BDU completed all work bouts (300 exercise min). Endurance was significantly reduced to 210 and 231 exercise min in CS and FH, respectively; only 5 of these 15 subjects completed all six work bouts. As shown in Table 1, despite increased water consumption in CS and FH, elevated SR produced WT deficits that were twice that of BDU. In order to maintain euhydration, CS and FH subjects would have had to drink 0.84L/hr. This requirement is 2.3 times greater than that necessary for subjects in BDU. Nunneley (3) recommended a minimum of 0.5 qts/hr for low intensity MOPP operations at ambient temperatures above 26.6°C. A significantly higher fluid intake rate during work was measured in FH compared to CS (Table 1) which is important when considering the need to drink during active work scenarios. However, CS compensated for this difference with higher intake rates during rest periods.

Table 1. Fluid Balance

	Sweat Rate (L/hr)	Cum Fluid Intake (L/hr)	Work Intake (L/hr)	Rest Intake (L/hr)	Rehydration ^a (%)	WT Loss (kg/hr)	WT Loss (%/hr)
BDU	0.37 ±0.04	0.25 ±0.05	0.25 ±0.05	0.27 ±0.09	70 ±11	0.24 ±0.02	0.32 ±0.03
CS	0.79 ^b ±0.07	0.35 ±0.04	0.28 ±0.04	0.70 ^b ±0.18	48 ±10	0.50 ^b ±0.08	0.68 ^b ±0.09
FH	0.89 ^b ±0.04	0.46 ^b ±0.07	0.42 ^{bc} ±0.06	0.60 ^b ±0.06	53 ±9	0.49 ^b ±0.09	0.65 ^b ±0.11

Values are mean±SE.

a % Rehydration = (Cumulative fluid intake/Sweat loss) x 100

b significantly different (p<0.05) from BDU

c significantly different (p<0.05) from CS

Table 2 illustrates that while BDU subjects displayed minimal increases in HR and Tre from pre-exercise during the chamber trial, CS and FH subjects encountered significant elevations in HR, Tsk and Tre. These temperature changes increased heat storage (S) (5) from pre-exercise in BDU by only 7±3 kcal/m² while for CS and FH heat storage increased, on average by 33±3 kcal/m². Overall, PV

did not change significantly between pre- and post-exercise in the BDU trial (an increase of $1.1 \pm 1.5\%$) while in CS and FH trials average PV decreased $7.6 \pm 1.9\%$ and $9.6 \pm 2.8\%$, respectively.

Table 2. Effect of clothing ensembles on heat strain indices

	Final Walk		Final Walk		Final Walk	
	HR	Δ HR	Tre	Δ Tre	Tsk	Δ Tsk
	(bpm)	(bpm)	($^{\circ}$ C)	($^{\circ}$ C)	($^{\circ}$ C)	($^{\circ}$ C)
BDU	86	7	37.56	0.39	33.92	-0.45
	± 3	± 2	± 0.08	± 0.10	± 0.18	± 0.15
CS	128 ^b	46 ^b	37.95	1.04 ^b	35.69 ^b	1.23 ^b
	± 5	± 6	± 0.13	± 0.11	± 0.20	± 0.20
FH	133 ^b	52 ^b	38.27 ^b	1.01 ^b	35.57 ^b	1.08 ^b
	± 4	± 4	± 0.13	± 0.07	± 0.27	± 0.27

Values are mean \pm SE.

Δ = Final walk - pre-exercise

b statistically different ($p < 0.05$) from BDU.

On a 6-point scale from "not at all" to "extreme", pre-exercise ESQ responses ranged from "not at all" to "slight" for all groups for weariness, headache, bodily aches, light-headedness and thirst. Post-exercise, there was a marked increase in the incidence of symptoms rated as "moderate" or "extreme" for CS and FH while BDU subjects perceived little change in heat-related symptoms over their pre-exercise responses. CS subjects experienced a greater incidence of headaches, thirst and heat-related symptoms than FH subjects; however, FH subjects drank slightly more than CS and consequently had a reduced WT loss, which may in part explain these findings. Nevertheless, these results are similar to those observed by Ryman and associates (4) in sedentary subjects wearing chemical protective clothing.

On a scale ranging from "very, very light" to "very, very hard", average rating of perceived exertion for the initial walk was lowest in BDU (fairly light), followed by FH (somewhat hard) and highest in CS (somewhat hard/hard). Upon completing their trial, BDU subjects rated their their final walk as somewhat hard while both the CS and FH groups rated their final walk very hard.

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